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TECHNICAL REPORT #
TR-76-32-FEL

EVALUATION OF MICROWAVE TEMPERING OF MEAT FOR USE IN CENTRAL FOOD PREPARATION FACILITIES

Project Reference: O&MA 728012.19

June 1976

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A 25 kW tempering tunnel was tested to determine its usefulness in armed service functions such as Central Food Preparation System (CFPS), where frozen meats are to be tempered to about 25°F, so that they may be further processed or broken down for subsequent handling. It was determined that cases of frozen meat as obtained from the supply system can be successfully tempered, and it is further believed that microwave tempering can be used advantageously by the armed services. There were variations in the temperature after tempering,

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TECHNICAL REPORT

EVALUATION OF MICROWAVE TEMPERING OF MEAT FOR USE IN CENTRAL FOOD PREPARATION FACILITIES

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PREFACE

As a result of several studies, the decision was made to continue development and to implement central food preparation systems (CFPS) where applicable in the Army. As part of the continued development, an interim CFPS has been planned for Fort Lee, Virginia and is currently being implemented. The US Army Troop Support Agency (TSA) has been charged with developing and implementing procedures, techniques, and providing guidance in connection with the installation.

Furthermore, US Army Natick Research and Development Command (NARADCOM) has been tasked with giving TSA technical support in the CFPS area. As part of this support, various pieces of production equipment have been purchased for test at NARADCOM to determine their suitability for use in CFPS. One of these pieces of equipment is a microwave tempering tunnel, and its evaluation is the subject of this report.

The following Food Engineering Laboratory personnel contributed to this report:

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Dr. George C. Walker

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A special acknowledgment is given to Mr. Grover D. Haigh for his efforts in collecting data and managing the supply of test products.

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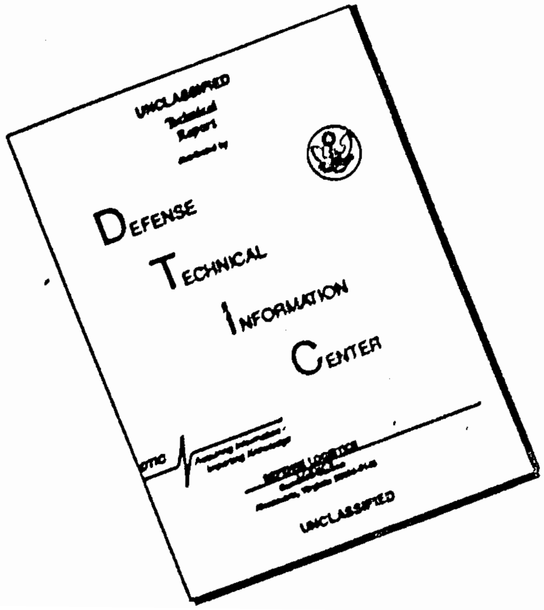

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INTRODUCTION

One of the basic operational requirements for Central Food Preparation Systems is to use, wherever possible, the food materials which are currently available through the Armed Services Food Supply System. This means that practically all meat products will be boneless and received in a frozen condition. Generally, these products are packed in corrugated fiberboard boxes weighing up to 75 lbs. with the most common weights ranging from 50 to 60 lbs.

Some products, such as frozen ground beef patties and fish fillets, can and should be cooked in the unthawed state. Such products are packed so that they can be separated into individual pieces while still frozen. Other frozen products such as roasts could be cooked in the unthawed state, but it is difficult, if not impossible, to break out the frozen product and arrange it properly in roasting pans. Therefore, this type of product should be tempered to a temperature above 25°F so that the pieces can be separated from each other. Still other products such as bulk ground beef and swiss steaks must be tempered or thawed so that they may be further processed before cooking.

It is estimated for a typical CFPS operation that a customer load of 25,000 people will require the tempering of 16,600 lbs of meat per day for use in the central kitchen plus 5,250 lbs. for use in satellite dining halls; or a total of about 22,000 lbs. to be tempered for each day of the week on a five-day work week schedule. This amount of material will occupy 550 cu. ft. of volume or 1650 cu. ft. if the good practice standard of 72 hours is used for tempering. These figures are based on 100% utilization of space. The actual requirements will probably be three times as great when allowances are made for aisle-ways, materials handling equipment, and operatio l flexibility. The figures will vary, of course, for each situation, but they are believed to be valid for preliminary design purposes (Walker, et. al. and Walker & Tuomy, 1975).[1,2]

The freezing point of meat is usually considered to be approximately 28°F. When meat is exposed to thawing or tempering the individual pieces will, as mentioned, become increasingly easy to separate as the temperature rises above 25°F.

Normally, the term "tempering" applies if the temperature is raised to and controlled within the 25 to 28°F range. The term thawing or defrosting applies when the temperature is raised above the freezing level.

1. Walker, G.C., H.T. Schlup and J.M. Tuomy, 1975. Requirements for 25,000 servings of items selected from the 42-day menu. USANDC Tech Report TR-75-71 FEL.

2. Walker, G.C. and J.M. Tuomy, 1975. Storage requirements for ingredients used in preparation of 25,000 servings of products from the 42-day menu. USANDC Tech Report TR-76-18-FEL.

A common method of thawing is to place the frozen meat in a $40^{o}F$ box or room and leave it there for up to 72 hours. This method is objectionable because it is time-consuming and can generate drip loss or "weeping" and sanitation problems. To thaw or defrost frozen products with microwave energy is impractical because of the increased power requirements and operational problems associated with the ice-to-water phase change. Water thawing is also used in industry, but this method was not considered for CFPS because its applications are limited and because waste water treatment would be something of a problem. Complete thawing is not necessary for CFPS since the major objective is to temper only to a level where the contents of a shipping case can be easily separated and removed from packaging material. In general, there is comparatively little information in the literature on thawing of meat. Bezanson (1975), [3] however, has summarized the available data and problems.

A number of methods have been suggested for tempering a frozen product. Many of these relate to controlled temperature cabinets for small scale operations. They are generally designed for items which have been removed from their shipping containers. The time required for tempering roast-size pieces in equipment of this type with forced air circulation at high velocity will range from 12 to 24 hours.

A rather common method of tempering is to place the product in a room where the temperature is maintained near the freezing point but low enough so that complete thawing cannot occur. Without forced air circulation the tempering time by this method can be as long as 72 hours. Unfortunately, the long residence time for room tempering promotes abuses which tend to lower the quality of the meat even to the point where it is prone to surface contamination. There is also a tendency with this method to process more meat than is actually required. The reason is that it is impossible to predict the exact quantities needed, and complications arise if there is a shortage at serving time. Supplying meat in excess of need is frequently a source of waste and, consequently, is a factor of considerable concern. In general, the faster the tempering process the more controllable are the logistics of a Food Service System.

Because of the long residence time and other problems associated with room tempering, industry is beginning to use microwave devices for tempering. Microwave energy is used commercially to temper both wrapped and unwrapped meat and meat in fiberboard cases. Ordinary packaging materials have little or no effect on the penetration of microwave energy. Most commercial installations temper a limited number of products on a continuous basis where the operations can be standardized and scheduled in a routine manner. With the Armed Serviced by contrast many different products must be handled on a piece-meal basis.

3. Bezanson, A. 1975. Thawing and tempering of frozen meat. Proceedings of Meat Industry Research Conference, American Meat Institute Foundation.

In considering the use of microwave energy, cognizance must be taken of the significant difference between the microwave properties of ice and water. The frozen material must be tempered to a point above 25°F to facilitate handling but below the ultimate thawing level in order to avoid undesirable localized heating and energy losses.

There has been some concern at NARADCOM about the possibility that non-uniformity of temperature with microwave heating will result in operational problems. This possibility has been discussed with commercial users of microwave equipment and the consensus is that temperature equilibrium can be achieved by allowing the product to stand at room temperature for an hour or less after tempering. Some temperature variation, however, can be tolerated for the intended applications.

With 25KW of microwave energy the tempering time can be reduced to less than 15 mins and with 50KW this time is halved. The advantages of better inventory control at these fast rates are obvious as is the possibility of tempering to a given temperature without thawing or drip loss, but there was a question as to whether or not these advantages could be realized in handling the wide variety of products used in CFPS. Because of the potential benefits, however, it was decided to procure a microwave tempering tunnel and test its performance with typical CFPS products at NARADCOM. This report covers the test work.

A description and photographs of the equipment are contained in Appendix A; material throughput data are contained in Appendix B, and operating procedures, in Appendix C. The tables, nomographs and sample calculations in the report are presented in English units. Conversion factors for metric equivalents are as follows:

Pounds (lbs) to kilograms (kg) multiply by 0.4536.

Inches (ins) to centimeters (cms) multiply by 2.54.

BTU per lb. to gr. calories per gr. multiply by 0.5556.

Degrees Fahrenheit (°F) to degrees centigrade (°C), subtract 32 and multiply by 0.5556.

PROCEDURE

Products to be tested were obtained from the Armed Forces Supply System. They included chicken pieces and whole fryers, stew beef, ground beef, beef roasts, pork roasts and pork slices. All were received in a frozen condition and packed in corrugated fiberboard cases with paper liners. Some cases were banded with metal strapping, but this was removed to avoid shielding effects in the microwave field. Products were stored in a 0°F freezer to which they were returned after tempering for re-testing at a later date.

Microwave tempering is influenced by the initial temperature of the product and the desired end temperature. These and other factors determine the throughput rate for a specified power level. The initial temperature at the beginning of our study was established by taking nine readings at three depths in a diagonal array in several cases of each lot. The measurements were made with a fast acting indicator pyrometer. We found little or no variation, particularly, if the product had resided in the freezer for at least four days. Subsequently, we steamlined the procedure and merely measured the temperature at the geometric center of a single case. This temperature generally corresponded to the temperature of the freezer. Tempered temperature readings were taken at three depths in a diagonal array making a total of nine for each box. Surface temperatures were taken at eight random locations. The target temperature for the tempered product was 28°F, at which level the thermocouple probe could be inserted without drilling a pilot hole. As a matter of interest, the resistance to inserting the probe was a good qualitative indication of the degree and uniformity of tempering. Raytheon Company has prepared comprehensive tables for predicting energy requirements and throughput rates. These tables are a source of basic information, but the data must be adjusted for each particular situation. To avoid this inconvenience we developed nomographs to correlate all the pertinent factors for tempering from 0°F to 28°F. The nomographs were used in setting up the initial conditions for each product in this study and are offered here as an example of a useful operational guide. A complete explanation of their use is contained in Appendix B. Table B1, shows typical products to be thawed for the Armed Forces and the calculated conveyor belt speed in terms of RPM to temper the products from 0 to 28°F.

The operation of the Raytheon tempering tunnel can be controlled by varying the conveyor belt speed and/or the power level. We decided for CFPS use to operate the unit at maximum power (25KW) whenever possible, and to control the tempering operation by varying the conveyor belt speed.

It became evident during the course of our tect work that two different modes of operation will be required to satisfy the anticipated needs of CFPS. One is a continuous mode where there is enough product in the system to establish steady state conditions. The second is a small lot mode where one to eight cases are to be tempered in an unsteady microwave environment. These two modes were studied separately. The data in Raytheon's tables apply to steady state conditions and can only be used directly for a continuous mode of operation. The tests to represent a continuous mode were conducted by placing 12 cases end-to-end on the conveyor belt and measuring the temperatures of cases #6 and #7. These are the only two in the line subjected to steady state conditions. In the small lot runs various numbers of cases were processed and temperatures were measured in all of them. Conveyor belt speeds and power levels were determined as indicated in Appendix B.

RESULTS AND DISCUSSION

Continuous Mode

Table 1 gives the temperature results for various products using the continuous mode. In most cases the average internal temperature of the two test cases after tempering with this mode of operation, was within a degree of the target and the extremes were within 2-1/2°F of the average. The average surface temperature ranged from 3 to 5 degrees higher than the average internal temperature, and the extremes ranged from 1-1/2 to 7° of the surface average. Average internal temperatures can be reproduced with minor variations. The run-to-run variations in surface temperatures, however, are slightly greater. Furthermore, there were no significant differences in internal temperature at the three depths where measurements were made. Table 2 shows the average tempered temperatures and the extremes for a number of products. Observations other than those listed in Table 2 are as follows:

Table 1. Continuous* Mode Results

Product	Target Temp. (°F)	Initial Temp. (°F)	Belt Speed (RPM)	Internal Temp. (°F) Ave	Max	Min	Surface Temp. (°F) Ave	Max	Min	Remarks
Chicken fryers	27	11	600	28.5	33	26	32.4	35	30	Giblets stuck
" "	28	7	415	32.2	40	29	37.3	47	32	" "
" "	29	5	310	30.2	32	27	45.0	77	32	" "
" pieces	28	6	360	29.2	32	27	34.8	43	32	Mostly frozen
" "	29	3	260	30.0	34	28	36.3	45	31	Partly "
Pork loins	27	5	900	26.8	29	25	35.2	41	32)	To demonstrate
" "	27	5	500	26.6	29	25	33.8	39	32)	reproducibility
" slices	28	3	445	28.5	32	27	33.1	39	31)	To demonstrate
" "	28	6	470	28.8	30	28	32.9	44	30)	reproducibility
Stew beef	25	7	780	23.2	25	21	31.9	34	30	Mostly frozen
Same + 1/2 hr @ 75°F	-	-	-	24.7	28	24	31.7	33	31	
Same + 21 hrs @ 40°F	-	-	-	28.1	29	27	31.7	35	30	Separable; some drip
Stew beef	28	10	470	28.2	30	27	38.4	39	30	Separable; drip on belt
Ground beef	28	4	420	28.4	30	27	32.5	34	31	Some frozen pockets

*Simulated by processing 12 cases end-to-end and measuring tempered temperatures in cases #6 and #7.

Whole chickens, raw

Whole chickens, raw, were packed in 22" x 18" x 7" cases having an average gross weight of 63 lbs. The giblets were wrapped in paper and partially contained in the body cavity. The objective of tempering was to raise the temperature so that the package of giblets could be easily removed. It was impossible to achieve this objective even though the temperature was raised to a point where surface overheating was evident. Temperature variations at all three levels of heating were greater than with any other product.

Chicken pieces

Chicken pieces were packed in four separate paperboard cartons and contained in a corrugated case having the same gross weight and dimensions as those for whole chickens. The objective was to raise the temperature to permit separation of the individual pieces. This was done by tempering to an internal temperature of 30°F at a rate of 1150 lbs. per hour. The carton-size blocks, however, did not fall apart without some twisting and bending..

Pork loin, boneless

The pork loins were packed in 25" x 14" x 6" corrugated cases having an average gross weight of 40 lbs. These were tempered at a rate of 870 lbs. per hour to within 1/2°F of the target and with minimum variations in temperature. They broke free of each other and the lining material.

Pork slices

Pork slices were packed in 21" x 17" x 6-1/2" cases having a gross weight of 55 lbs. The slices were arranged in layers with paperborad and polyethylene separators. Individual slices were completely separable when tempered to 29°F at a rate of 1890 lbs. per hour.

Stew beef

The stew beef had been previously bulk-packaged in 21" x 15" x 6" cases having an average gross weight of 49 lbs. The contents could be dumped and readily separated into individual pieces when tempered to a temperature of 28°F at a rate of 1670 lbs. per hour.

Beef, ground

The ground beef was packaged in eight separate polyethylene bags contained in a 21" x 5" x 5-1/2" corrugated case having an average gross weight of 50 lbs. It was tempered to a temperature of 28.4°F at a rate of 1540 lbs. per hour. The tempered product was suitable for immediate use in formulating products, such as chili and barbecued beef, but was judged to be too stiff for patty-making in a Hollymatic forming machine.

Small Lot Mode

This mode of operation was investigated by tempering from 1 to 8 cases at a time; the temperature results are shown in Table 2. Results indicate that the final temperatures with four or more cases were generally as predictable but slightly less uniform than for a continuous mode of operation. With less than 4 cases, the final temperatures were about 2°F lower than predicted and the variations were significant. Furthermore, when tempering less than 4 cases it is necessary to operate the microwave generator and belt at reduced power and speed to avoid difficulties with the transmitter. The procedure is to operate the transmitter at half-power (1.1 amps on the level meter) and the belt at half or less than the calculated RPM. Better temperature predictability can be achieved with one or two cases by applying the following factors to the belt speed:

Table 2. Small Lot Results

Product	No. of Cases	Target (°F)	Calc. Speed	Adj. Speed	Case Posi-tion	Internal Temp.(°F) Ave	Max	Min	Surface Temp.(°F) Ave	Max	Min	Power KW
Stew Beef	1	28	540	220	1	27.1	31	23	32.1	35	30	12.5
" "	2	28	460	210	1	27.2	31	24	33.4	31	25	12.5
					2	27.4	40	31	35.4	52	31	
" "	3	28	460	230	1	26.1	30	21	33.9	36	32	12.5
					2	28.7	31	26	31.0	34	30	
					3	27.8	29	24	30.6	33	29	
Pork Slices	8	28	500	500	1	25.8	30	23	33.9	35	31	25.0
					2	27.0	29	25	32.0	33	31	
					3	26.9	29	25	31.3	33	30	
					4	27.3	30	25	31.3	33	30	
					5	29.0	33	25	31.9	33	31	
					6	28.3	30	26	32.0	34	31	
					7	28.6	32	27	33.4	38	32	
					8	26.3	28	25	33.9	36	31	
Ground Beef	4	28	480	480	1	26.8	32	24	33.6	39	31	25
Stew Beef					2	27.6	29	25	32.8	35	32	
Chicken pcs					3	29.3	32	26	33.9	40	31	
Pork Loins					4	30.0	32	27	33.3	37	32	
Pork Loins	4	28	670	670	1	23.7	26	20	40.2	47	34	25
					2	27.0	28	26	34.7	41	32	
					3	27.7	28	27	33.2	36	32	
					4	26.7	28	24	35.3	48	31	

No. of Cases	Factor
1	0.8
2	0.9

If for example, it is desired to temper a single case, the belt speed is calculated as described in Appendix B. This figure is reduced by half to compensate for the reduction in microwave power and then further reduced by the indicated factor. For example, if the calculated belt speed is 400 RPM, then for a single case at half power and adjusted for cavity losses the actual speed will be: 400 x 1/2 = 200 x 0.8 = 160 RPM. The average internal temperature will now be close to that predicted, but the extremes will be significantly greater than for a continuous mode of operation.

Meats and poultry can be tempered in a 25KW Raytheon microwave tunnel from a temperature 0°F to 28°F within twelve minutes when processing four or more cases at a rate of about 1600 lbs per hour. When tempering fewer than four cases, the time will be doubled since it is necessary to operate at half the power and speed to avoid problems with the transmitter.

Operation flexibility is excellent. The machine can be started with the sequential flip and push of a few switches and buttons, and belt speed can be regulated at will with a twist of a knob and a look at a tachometer. The microwave power supply is adjustable from 0 to 25KW, but the preferred mode of operation is to maintain the power at fixed levels and vary the belt speed for any particular situation. Several aids such as tables, nomographs and formulae have been prepared to simplify the determination of belt speeds and the switching of microwave power. Once the belt speed has been established for a particular set of conditions and a particular product, it will always be the same. If, for example, the belt speed to temper ground beef from 0 to 28°F is 410 RPM it will never change, assuming the case dimensions, weight, percent fat and temperature conditions remain the same. Belt speed, however, is not too critical as evidenced by the observation that it takes a 100 RPM change in speed to effect a 1°F change in the tempered temperature.

A target temperature of 28°F appears to be most satisfactory for a majority of products. At higher temperatures, there is a risk of localized overheating and drippage in the cavity and on the conveyor belt. Dripping is obviously objectionable since it represents a loss and necessitates an avoidable cleaning operation. At temperatures below 28°F, there will be spotty areas which remain solidly frozen. Even at 28°F there are small frozen pockets as evidenced by resistance when inserting a thermocouple probe.

Products such as ground beef and stew beef which are solidly packed generally temper more uniformly than items such as whole chickens and roasts which are packed with inherent voids. Exceptions are pork loin and slices which tempered very uniformly in spite of the voids. Whole chickens with bagged giblets in the cavity are a problem, since it is impossible to temper and remove the bag without the risk of objectionable overheating. The body meat appears to temper satisfactorily, but the bags of giblets refuse to break loose. In all probability it will be necessary to follow microwave tempering by a period of room tempering for this particular product.

When it is known that a product has been in storage long enough to reach the 0° temperature of the surroundings the freezer temperature can be assumed to be the initial temperature for deriving the belt speed. If the storage history is unknown, it is advisable to measure the initial temperature rather than run a sample case through the machine as a trial balloon. The initial temperature should be the average of a minimum of four readings from a representative case.

Four variables must be considered - initial temperature, gross weight, case dimension and percent fat - in deriving the belt speed for the desired final temperature. The first three of these factors can be readily measured and it is important that they be known with a reasonable degree of accuracy to compensate for the fact that the percent fat will normally be an approximation. With knowledge of these factors, based on measurement and experience, it is possible to obtain an average internal tempered temperature with a fraction of a degree of the target. There will be some deviations, particularly with the small lot mode of operation. When the average internal temperature is 28°F, the span between the extremes may be as much as 7°. Normally, the span is less than four. The lowest temperature is almost always at the geometric center of the container. The average surface temperature will be around 6° higher than the internal average and the span between the extremes will be about the same.

Some concern has been expressed that the non-uniformity of temperatures obtained in the microwave tempering might cause production problems. Reports of informal visits by NARADCOM technologists to commercial installations using microwave tempering indicate that additional tempering by allowing the product to stand for periods of less than one hour will permit equilibration of temperatures to such a degree that even pressing and forming of the meat can be carried out.

CONCLUSION

Our work has shown that microwave tempering is a most important and useful component of a central food preparation system. The tempering equipment is easy to operate, it can be adjusted to most specific product tempering requirements, and the cost factors involved are, though higher than those of other tempering methods, justified by the greater accuracy and better control attainable in microwave tempering. Our nomographs for determining belt speed for tempering greatly reduces the somewhat cumbersome tables supplied by Raytheon.

APPENDIX A - EQUIPMENT

The microwave tempering equipment tested for use in central food preparation systems consists of a Raytheon Model QMP 1679C tunnel and a 915 MHz "Mark" 50 B transmitter. The transmitter is a separate unit which is to be located in a protected area to avoid exposure to water and steam. It is connected to the cavity of the tunnel by means of a split waveguide arrangement. The tunnel includes an 8' entry section, an 8' take-away section, and an 8' cavity or applicator in between. The entrance and take-away sections are designed to dissipate any stray microwave energy from the cavity. The overall length is about 33'. A one-piece three-ply butyl dacron belt conveys the product through the tunnel at speeds which are controllable from 0.3 FPM (140 RPM) to 3.5 FPM (1640 RPM). The tunnel opening is 10" x 22", which will accommodate an estimated 98% of the cases to be processed at a central food preparation facility.

Utility requirements include cooling water and electric power. Cooling water for the transmitter ranges from 2.5 GPM @ 40°F to 5.0 GPM @ 90°F. For the tunnel the range is 1 to 3 GPM. When permanently installed, the supply to each unit should include an orifice or "Kates" regulator to control the flow.

The transmitter is designed to operate directly from a 460 volt 3 phase 60 cycle source of electric power. An accessory transformer is available for 208 volt service. The current requirement at 460 volts is 50 amps. Sixty cycle power for the tunnel is received from the transmitter.

Tempering or partial thawing of frozen meat with microwave energy on a commercial scale is relatively new. It is unique for this application because the energy, at the frequency used (915 MHz), deeply permeates the product to minimize surface thawing and temperature gradients. Typically, a frozen product can be tempered with 25KW of microwave power in about 12 minutes as compared with 2 to 3 days in a tempering room.

Microwaves, which are a form of electromagnetic radiation, are generated in a transmitter and directed to the cavity section of a tempering tunnel by means of a waveguide. The rays of energy penetrate the frozen meat to raise its temperature. Unabsorbed rays bounce around inside the cavity, being reflected by the interior metal surface and losing a certain amount of energy with each passage through the meat. The residual energy is finally absorbed in the attenuating tunnels attached to the opposite ends of the cavity.

A 25KW transmitter such as that used for the QMP 1679C Raytheon tunnel delivers about 66,000 BTU to the frozen product. This means that 33 BTU/lb are applied for a 2,000 lb/hr operation. The heat requirements and consequently the throughput rate depend on the fat content and the initial and final temperature of the product being tempered. Fat content and temperature data are correlated with throughput rates and heat requirements in a tabulation furnished with the machine.

The estimated cost of operating the 25KW Raytheon tunnel at a typical CFPP will range from 1.02 to 1.85 cents per pound, depending on the rate of depreciation - 20 years for the first figure and 10 years for the second. Both costs are based on tempering 600,000 pounds of meat per year for 25,000 men. The 1.85-cent figure was derived as follows:

Estimated Operating Cost

Capital investment	-		$100,000
Tempering rate	-	2,000 lbs/hr	
Operating period	-	300 hrs/yr	
Depreciation @ 10%	-		10,000
Power (36KW @ $0.025/KWH)	-		300
Tube replacement	-		800
Total annual cost	-		$ 11,100

Unit cost: $\frac{11,100 \times 100}{600,000} = 1.85$ c/lb

It is to be noted that the operating cost is also sensitive to the throughput rate. The projected rate is 600,000 lbs/yr or the equivalent of only 300 hours of operation. If the machine were operated at designed capacity for 40 hours per week, 50 weeks per year, the annual throughput would approximate four million pounds. Under these conditions and assuming a ten-year write-off the operating cost would be around 0.39 rather than 1.85 cents per pound.

The added cost of microwave tempering is justified in part by better yields, savings in floor space and handling, improved quality and sanitation, and particularly, greater operational flexibility.

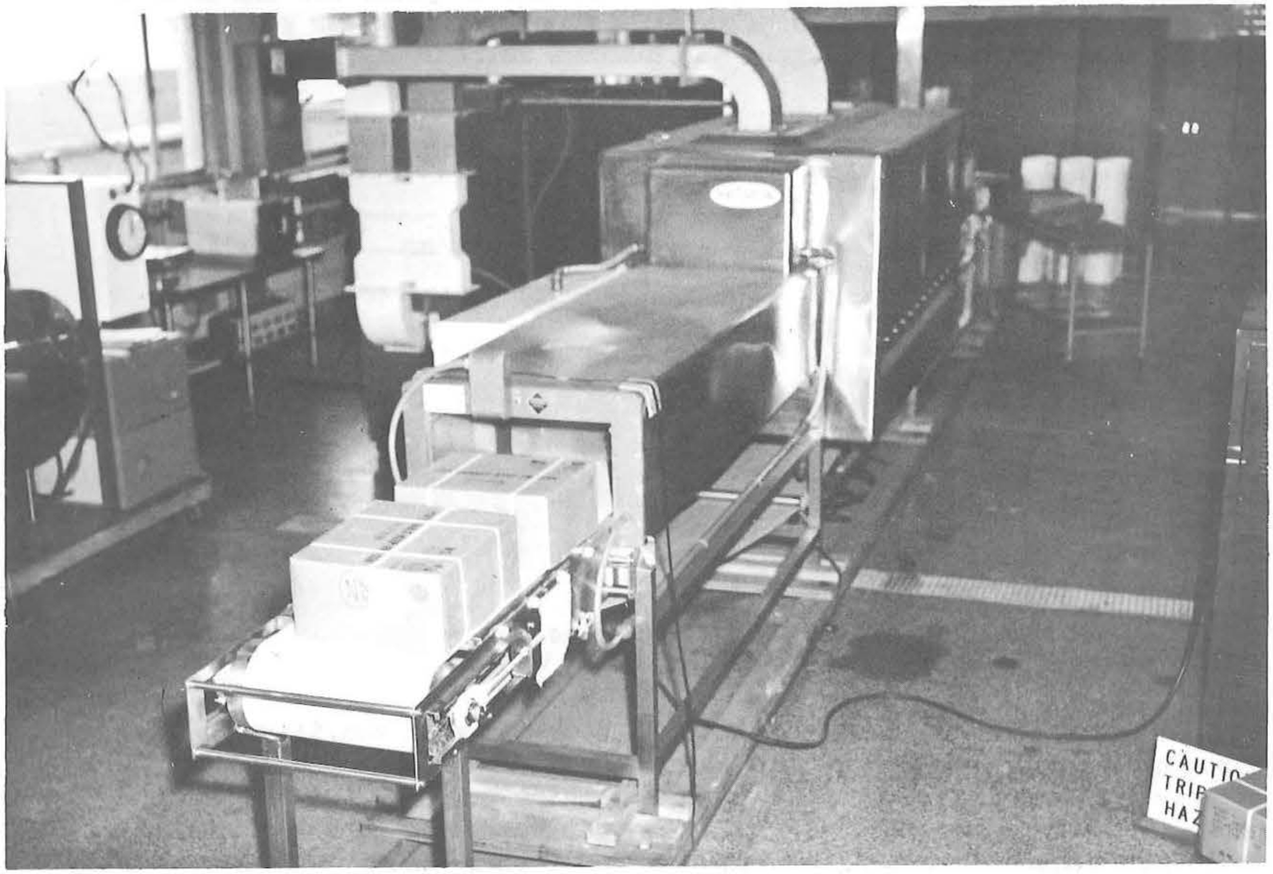


Figure A1. Overall View Showing Waveguide Connections Between Transmitter and Cavity.

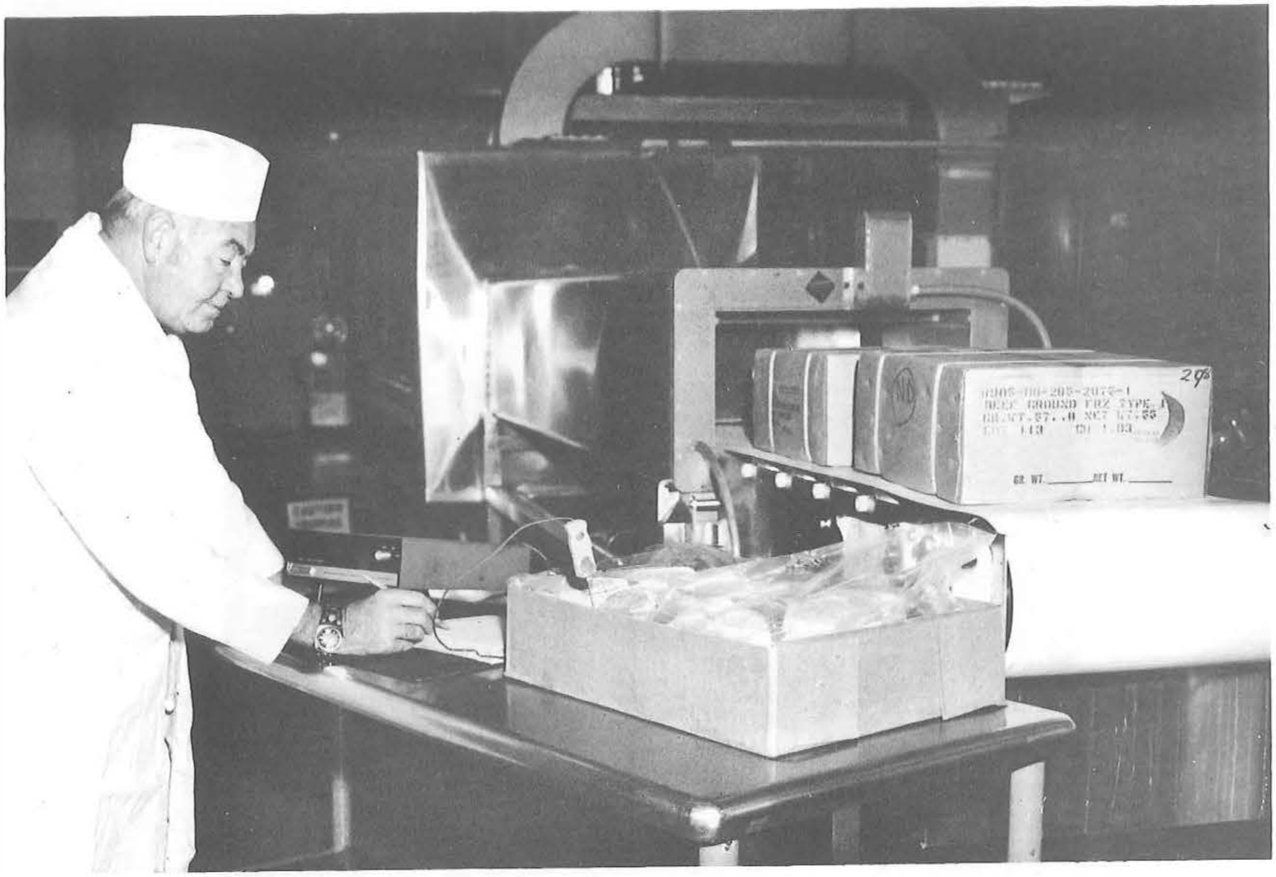


Figure A2. Checking Temperatures at Delivery End

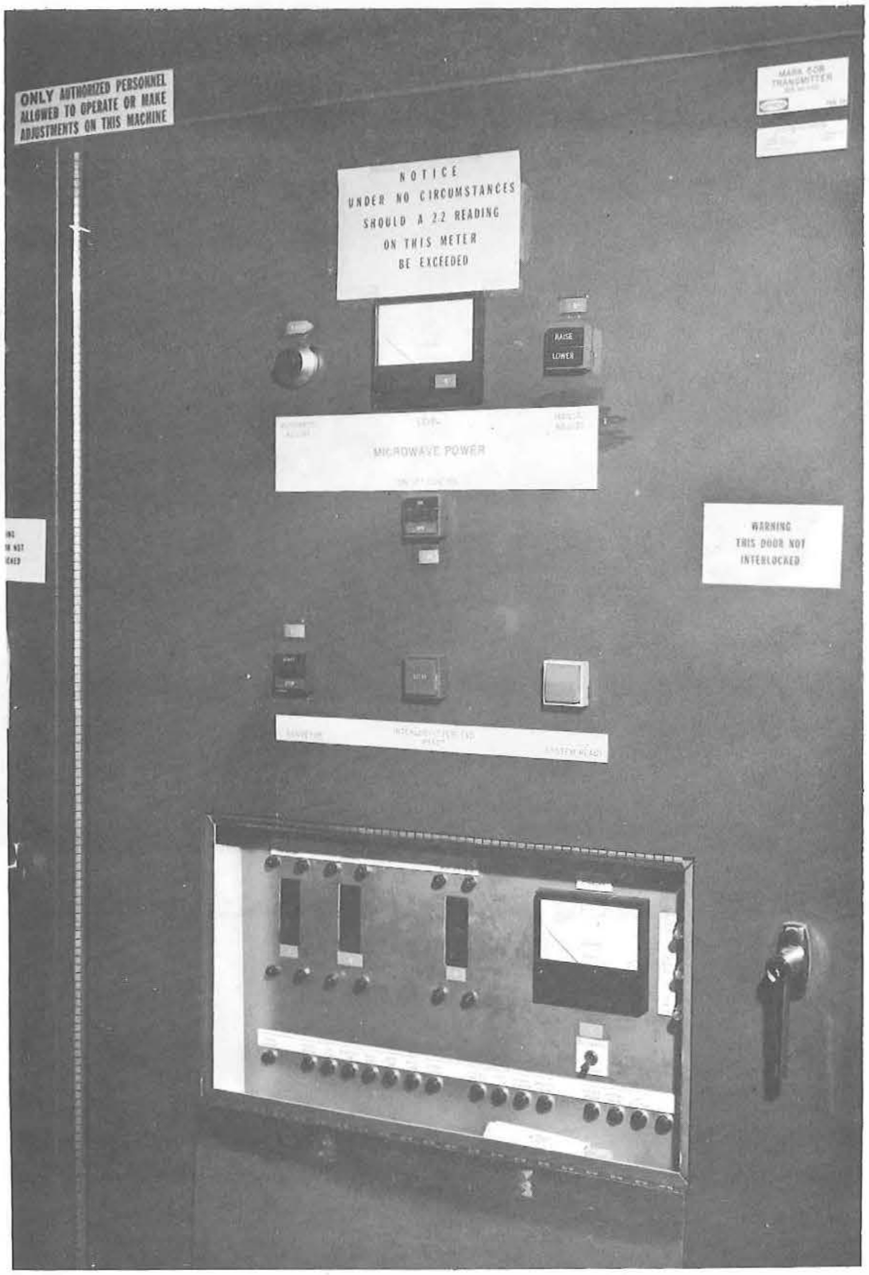


Figure A3. Transmitter Control Module

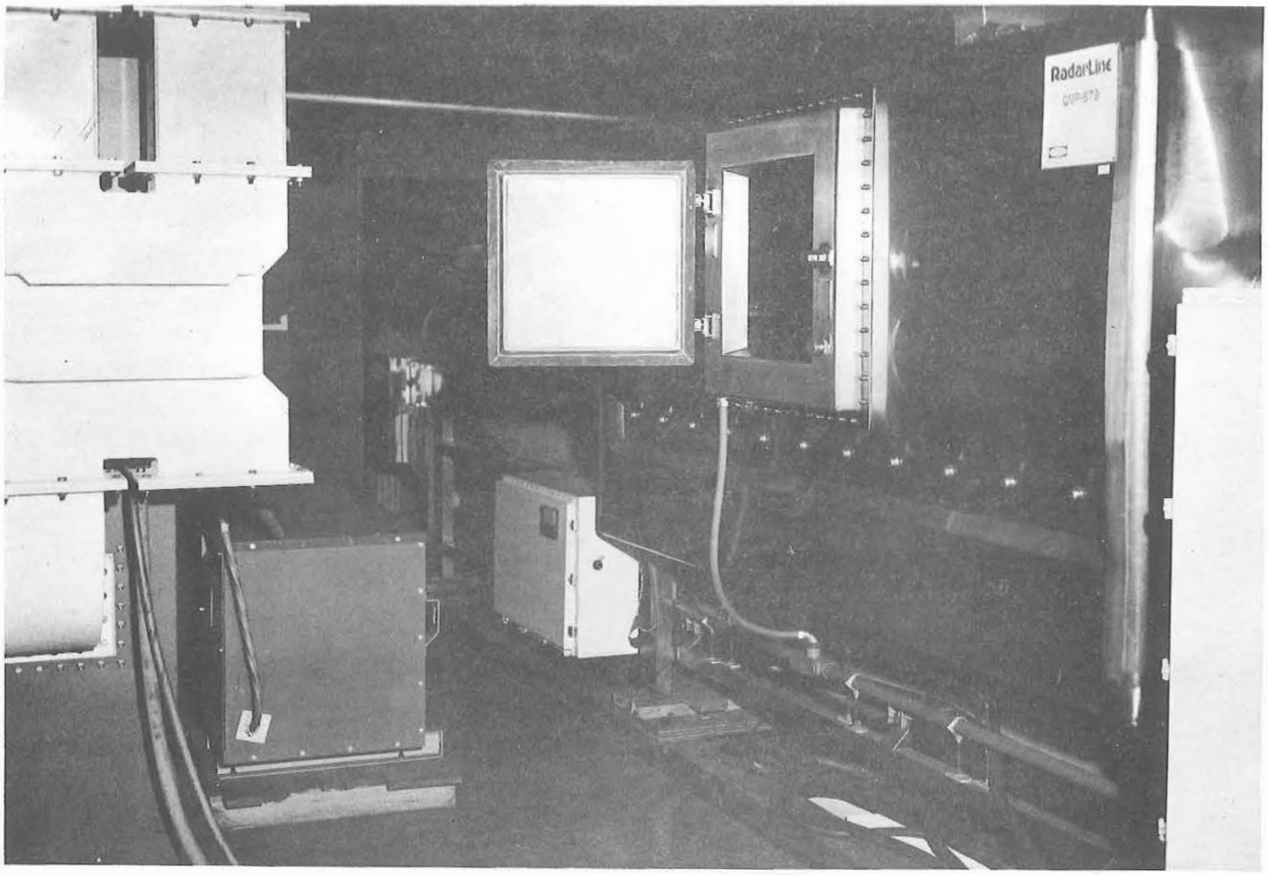


Figure A4. Side View Showing Cavity Door and Section of Waveguide

APPENDIX B: Throughput

Microwave tempering depends on the time a product is exposed and the intensity of applied energy. The usual procedure for continuous operations is to operate the microwave transmitter at full power (25KW) and vary the belt speed. Belt speed then is the only variable, but it must be established for each product. This can be done by the use of nomographs or a simple calculation. In either case, it involves a consideration of initial and final temperatures, product composition, and load distribution on the conveyor belt. The initial and final temperatures and the product composition establish the pounds per hour or mass throughput rate that can be tempered with the available energy (25KW). The throughput rate for various temperatures and meat compositions have been determined by Raytheon, Inc., for a 25KW tempering tunnel. These are included with the maintenance manual which is supplied with the machine.

A nomograph (Figure B1) has also been prepared as a supplementary source of information.

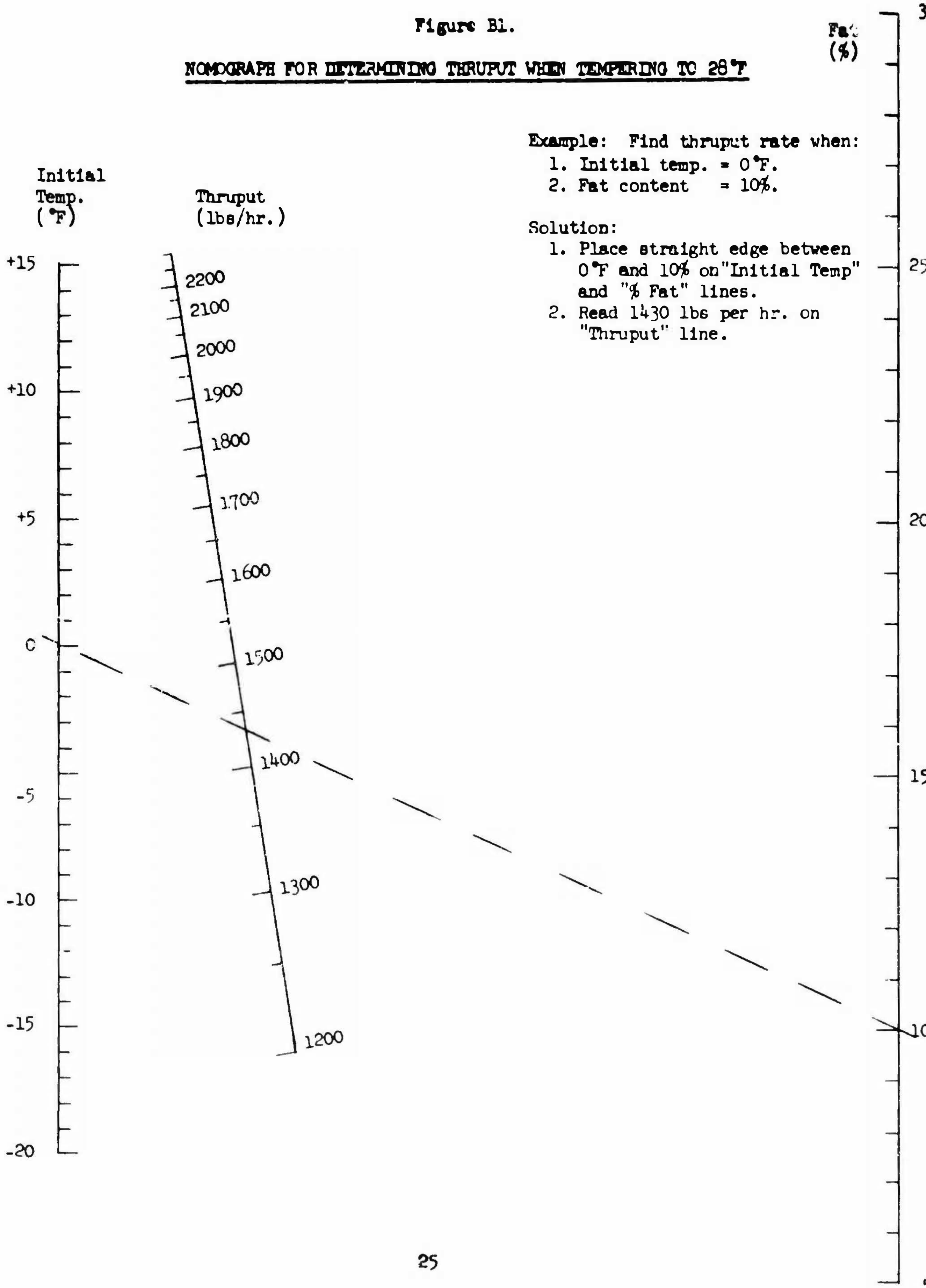
The throughput rate in pounds per hour must be adjusted to show the load distribution on the conveyor belt. This adjustment is made by accounting for the gross case weight and the long dimension which represents its lengthwise positioning on the belt. Thus, the belt speed in RPM is derived as follows:

$$\text{RPM} = \frac{\text{Mass flow (lbs/hr)} \times \text{Case dimension (length in inches)}}{\text{Gross case weight (lbs} \times 1.54)}$$

The 1.54 figure in the denominator is a factor to convert belt speed in inches per hour to the scale of the tachometer (RPM).

Figure B1.

NOMOGRAPH FOR DETERMINING THRUPUT WHEN TEMPERING TO 28°F



Example: Find thruput rate when:
1. Initial temp. = 0°F.
2. Fat content = 10%.

Solution:
1. Place straight edge between 0°F and 10% on "Initial Temp" and "% Fat" lines.
2. Read 1430 lbs per hr. on "Thruput" line.

Suppose for example, it is desired to temper stew beef containing 10% fat and packed to a gross weight of 55 pounds in cases 24" long.* The initial temperature is 0°F and the final temperature is to be 28°F. What is the belt speed? Refer to the 90°F lean meat section of Raytheon's tabulation. Follow down "Starting Temperature" column on the left to 0.0; move to the right and read 1429 in the 28°F "Ending Temperature" column. The 1429 figure is the mass throughput rate in pounds per hour. Now insert this figure along with the case weight and length figures in the above expression for an answer of:

$$\frac{429 \times 24}{55 \times 1.54} = 404 \text{ RPM}$$

Belt speed can also be determined directly from the two nomographs (Figures B1 and B2) - mass throughput is obtained from Figure B1 and RPM from Figure B2. Their use is self-explanatory. The nomographical answer to the above example is 410 RPM. The difference between the two figures is insignificant.

The use of Raytheon's table is more accurate than the nomographs, but it is also more cumbersome, particularly when it is necessary to interpolate for fat content and initial temperatures. Furthermore, a high degree of accuracy in calculating belt speed is not necessary because the fat content is not always known nor is it constant from case-to-case. Neither is belt speed particularly critical. Figure B3 illustrates for the example cited above that the final temperature of the product is only changed about one degree for a 100 RPM change in belt speed.

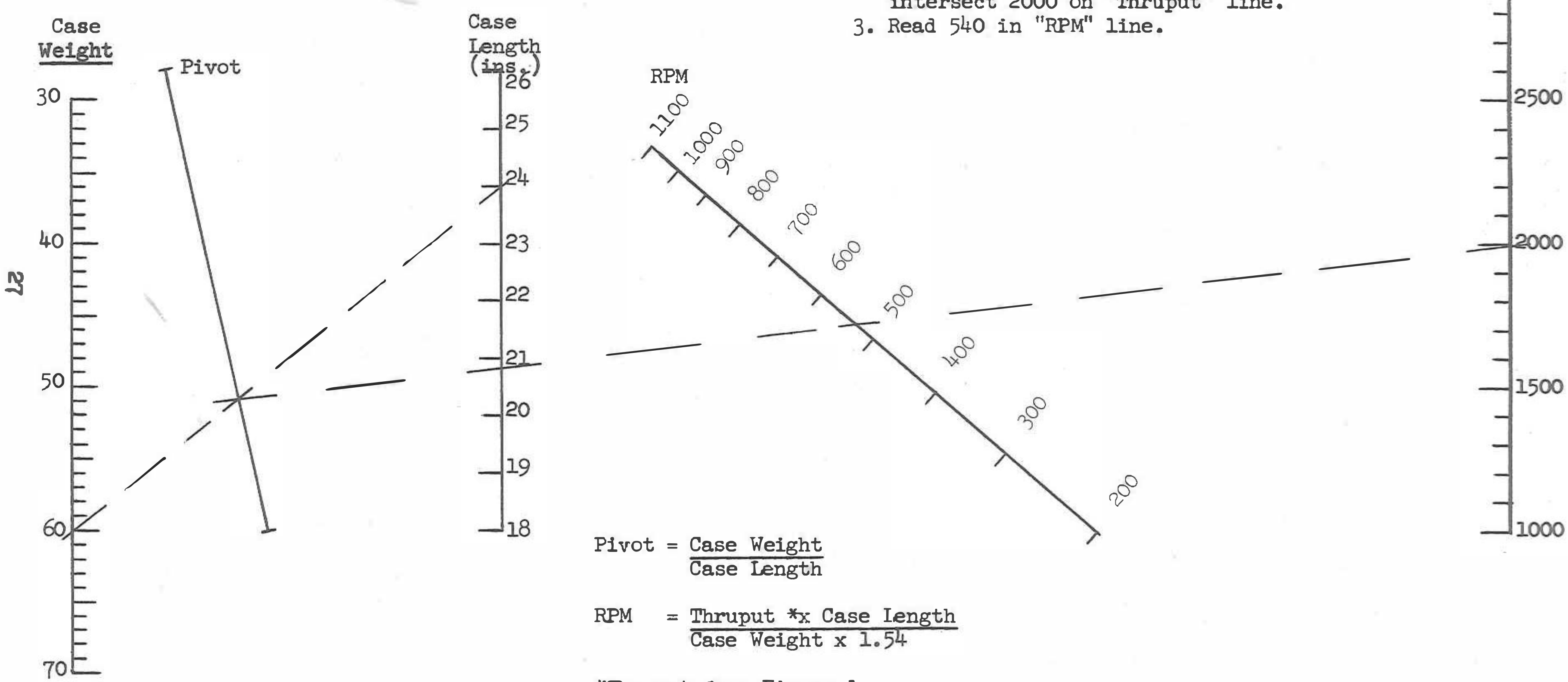
* The long dimension of a case is generally greater than the width of the tunnel opening, and it is necessary therefore to orient the long dimension so it coincides with that of the belt.

Figure B2.

NOMOGRAPH FOR DETERMINING BELT SPEED (RPM) WHEN TEMPERING TO 28°F

Example: Find RPM when:
1. Case weight = 60 lbs.
2. Case length = 24 ins.
3. Thruput = 2000 lbs per hr.

Solution:
1. Intersect 60 on "Case Wt" line and 24 of "Case Length" line w/straight edge.
2. Pivot straight edge on "Pivot" line and intersect 2000 on "Thruput" line.
3. Read 540 in "RPM" line.



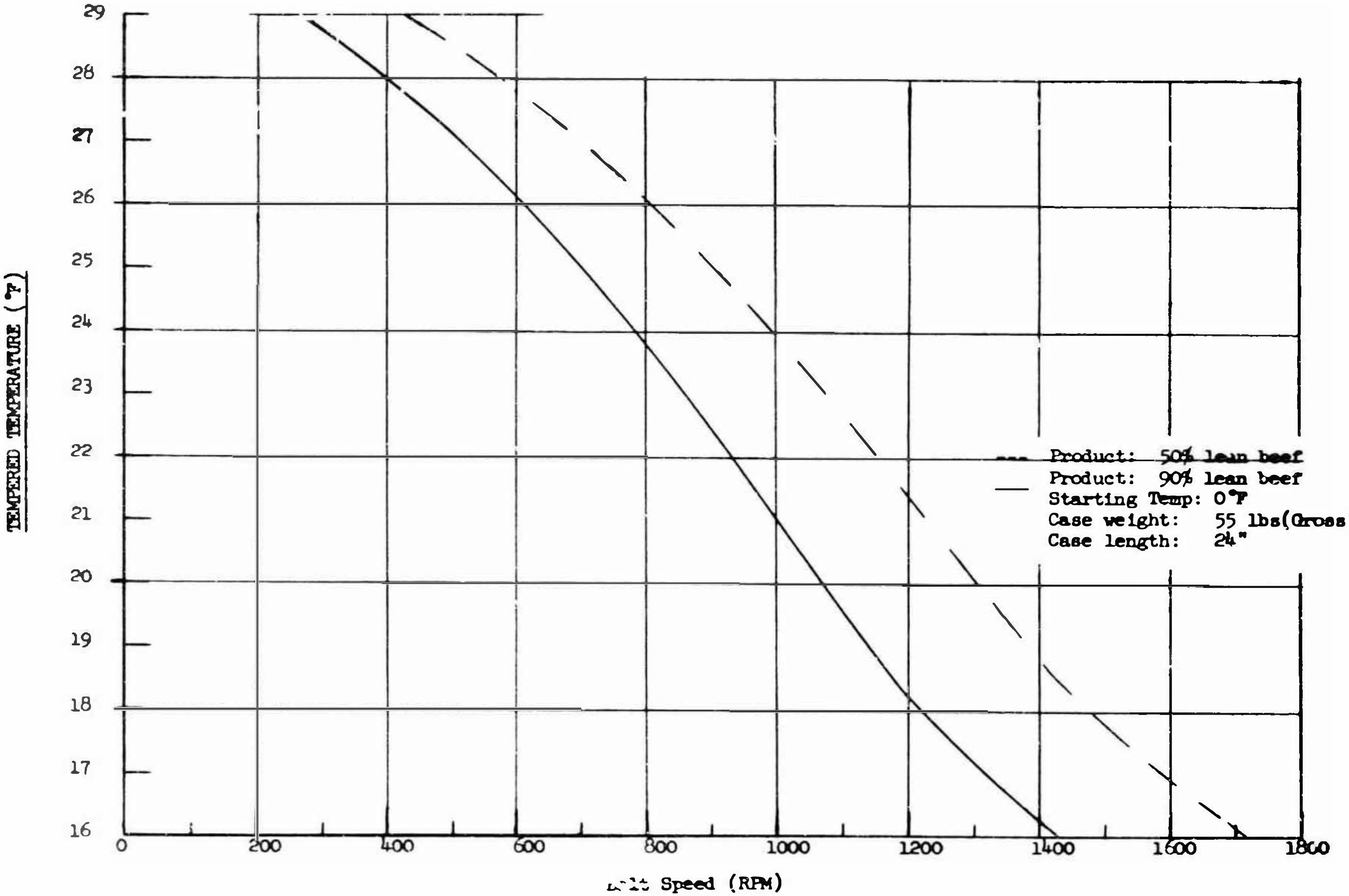
$$\text{Pivot} = \frac{\text{Case Weight}}{\text{Case Length}}$$

$$\text{RPM} = \frac{\text{Thruput *x Case Length}}{\text{Case Weight x 1.54}}$$

*Thruput from Figure 1.

JS: 11/75

Figure B3: EFFECT OF BELT SPEED ON TEMPERED TEMPERATURE



Appendix B, Cont'd

Belt speeds for a number of typical CFPF products have been presented for reference in Table B1. They assume an initial temperature of zero and a final temperature of 28°F. Belt speeds for other products or for situations where the initial and final temperatures are other than 0 and 28°F can be derived as explained above. For boney items such as whole chickens, it can be assumed that the bone and fat react the same when exposed to microwave energy and that the total percentage of the two can be used to calculate belt speeds. It may be necessary at times, because of unknown factors, to correct a deviation in the target temperature by trial and error. A suggested guideline is that a 100 RPM change in belt speed is equivalent to about a 1°F change in product temperature - the temperature varying inversely with the change in speed.

TABLE B1. Belt Speed (RPM) for Typical Frozen Meats (Continuous Mode)

FSN	Product	Gross Case Wt(lbs)	Case dimensions (ins)	% * Fat	% * Bone	Mass Flow (lbs/hr)	*** RPM	Remarks
00-551-9910	Bacon, Slab, Frozen	75	25.7 x 12 x 10	70	-	2638	590	-
00-133-5884	Beef, Bnls, Frzn, Chuck Short Ribs**	-	- -	11	-	1441		
00-133-5886	" " " Oven Roasts	54	20.0 x 15 x 5	11(Rnd)- 30(chuck)-		1441 1687	350 410	
00-133-5887	" " " Pot Roasts	54	20.0 x 15 x 5	26	-	1631	390	
00-133-5888	" " " Round	8[illegible]	34.5 x 21.5 x 13	14	-	1476	-	No go.****
00-133-5889	" " " Swiss Shanks	57	20.0 x 15 x 5	20	-	1547	350	
00-299-1316	" Corned, Frozen	65	24.0 x 12 x 9	10	-	1429	340	
00-138-7180	" Cutlets " Unbreaded	**	**					
00-177-5017	" Dried "	54	20.0 x 15 x 5	12	-	1453	350	
00-252-7978	" " " Chipped	65	24.0 x 12 x 10	6	-	1389	330	
00-285-2075	" Ground, Frozen	54	21.0 x 16 x 6	24	-	1603	410	
00-582-1323	" Tenderloin "	54	21.0 x 15 x 5	36	-	1787	430	
00-127-8229	" Liver, "	27	16.0 x 12 x 6	4	-	1368	530	
00-080-5280	Bockwurst, "	**	**	24	-	1603	-	
00-582-1346	Bologna, "	65	20 x 12 x 9	28	-	1659	330	
00-080-5318	Bratwurst, "	66	18 x 13 x 11	24	-	1603	-	No go.

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Table B1 Cont'd

FSN	Product	Gross Case Wt(lbs)	Case di-sions (ins)	% * Fat	% * Bone	Mass Flow (lbs/hr)	*** RPM	Re-marks
00-419-4320	Canadian style bacon, frzn,unsliced	**	**	18	-	1523	-	
00-965-2128	Chicken, Frzn, Cutup(w/o giblets,etc)	65	22 x 17.5 x 8.3	5	41	1976	430	
00-126-3416	Chicken " Whole	60	23 x 17 x 8.2	4	32	1737	440	
00-044-1869	Chitterlings, frzn, pre-cooked	65	26.9 x 17.8x7.5	-	-	-	-	
00-682-6643	Ham, cooked, frzn, smoked	53	20 x 12 x 9	28	-	1659	410	
00-926-1599	Lamb, roast, frzn	54	20 x 12 x 9	21	-	1561	380	
00-127-8208	Liver, Sausage, frzn	65	20 x 12 x 9	4	-	1368	270	
00-164-0488	Lobster, frzn, whole	28	21 x 12 x 11.5	0	-	1328	-	No go.
00-682-6816	Luncheon Loaf, frzn	65	24 x 12 x 10	13	-	1464	350	
00-118-2372	Pepperoni, frzn, dry	26	15.4 x 8 x 5.3	26	-	1631	630	
00-044-1854	Pigs feet, frzn	32	17 x 11.5 x 6	15	80	4122	1420	
00-080-5805	Polish sausage, frzn	11	10.3 x 8.4 x 5.8	26	-	1631	990	
00-126-4062	Pork butt, frzn	53	20 x 12.5 x 9	29	2	1704	420	
00-491-7209	Pork, Cntry style ribs, frzn	50	**	17	43	2312	-	
00-753-6503	Pork, dried, frzn	53	20 x 12 x 9	30	-	1687	410	
00-753-6426	Pork, ham, frzn	53	20 x 12 x 9	28	-	1659	410	

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Table B1 Cont'd

FSN	Product	Gross Case Wt(lbs)	Case dimensions (ins)	% * Fat	% * Bone	Mass Flow (lbs/hr)	*** RPM	Remarks
00-582-1345	Pork loin, frozen	54	30 x 11 x 10	24	-	1603	580	
00-753-6568	Pork roast, " , bnls	53	20 x 12 x 9	24	-	1603	390	
00-126-8743	Pork spareribs "	53	20 x 12 x 9	23	38	2345	570	
00-126-8724	Pork tenderloin"	53	21 x 16 x 6	10	-	1429	370	
00-044-1879	Pork hocks "	32	17 x 11.5 x 6	-	-	-	-	
00-273-3622	Rabbit, frozen, cutup	65	22 x 17.5 x 8.3	-	-	-	-	
00-080-6007	Rock Cornish hen, frzn	18	22 x 18.3 x 3.9	10	32	1895	1490	
00-299-1330	Salami, frozen	65	24 x 12 x 10	26	-	1631	390	
00-164-6874	Scallops, "	60	16 x 13 x 12	0	-	1328	-	No go.
00-080-7132	Scrapple, "	**	**	14	-		-	
00-582-4039	Shrimp,frzn,raw peeled, deveined	58	19 x 17 x 13	1	-	1338	-	No go.
00-127-8212	Thuringer, frozen, smoked	65	24 x 12 x 10	25	-	1617	390	
00-582-4042	Turkey, bnls, frzn, cooked	68	31 x 16 x 5.5	15	-	1489	440	
00-543-7333	Turkey, frzn, ready-to-cook,whole	125	32 x 22.5 x 9	11	27	1821	-	No go.

Table B1, Cont'd

FSN	Product	Cross Case Wt(lbs)	Case dimensions (ins)	% * Fat	% * Bone	Mass Flow (lbs/hr)	*** RPM	Remarks
00-139-8480	Veal, cutlets, frozen	**	**	11	-	1441	-	

* From "Composition of Foods" USDA Handbook No. 8

** Procured locally. Case weight and dimensions vary.

*** To raise temperature from $0^{o}F$ to $28^{o}F$.

**** Case too high to pass portals.

Appendix C. - Operation

The switching of microwave power was done in accordance with Raytheon's recommendations. The recommended procedure was to turn the power on when the leading end of the first case reached the center of the cavity and to shut it off when the trailing end of the last case is in the same position. Knowing where the lead and trailing ends of a case is, however, a problem since the cavity is sealed when the machine is in operation. Initially, the switching was done by a case count method based on the length of the tunnel and the assumption that the critical dimension of a case is 24 inches. The distance from the center of the cavity to either end of the tunnel is 12' which means that the power is to be turned "on" when the trailing end of the 6th case enters the tunnel and turned "off" when the lead edge of the 6th case from the end of the line reaches the discharge opening. This is a cumbersome procedure which is based on the assumption that the long dimension of a case is 24". To simplify the operation the belt was marked and numbered at 24" or 2' intervals. Now the procedure is to note the numbered mark in line with the lead end of the first case, add 6, and when the combined number on the belt reaches the tunnel entrance the power is switched on. Similarly when the trailing edge of the last case enters the tunnel the number on the belt is noted to which 6 is added and when the total of the two reaches the entrance the power is switched off. If, for example, four cases are to be tempered end-to-end and the lead edge of the first case is in line with mark #6 on the belt the microwave power is to be turned "on" when mark #12 reaches the tunnel entrance and turned off when mark #16 is in a similar position. The total number of 2' belt marks is 33 and when the on/off positions exceed this number a subtractive adjustment must be made. Suppose the lead edge of a four-case lot is in line with mark 30 in the belt, then the on/off positions will be 36 and 40, respectively. Since these numbers do not appear on the belt it is necessary to subtract the total of 2' belt marks (33) from 36 and 40 to obtain 3 and 7 for the microwave power "on/off" positions.

Continuous mode operation

Detailed procedures for steady state operations are contained in Raytheon's QMP 1679C Microwave Tunnel Operating and Maintenance Manual (Pt 2980-4). The following is a streamlined version which has proven to be convenient for day-to-day operations. Valves and controls can be identified by either the name or the letters and numbers in parenthesis:

TO START:

1. Open cooling water valves ("A" and "B").

2. Flip "Standby" toggle switch (#1) to ON position.

3. Flip "Control" toggle switch (#2) to ON position.

4. Push "Conveyor Start" button (#3).

5. Turn speed control knob (#4) for desired RPM.

6. Flip "High Voltage" toggle switch (#5) to ON position.

7. Flip "MODE" toggle switch (#7) to "MANUAL" position.

8. When "READY" light is ON and leading end of 1st case is at center of cavity - push "Microwave Power On" button (#6).

9. Jog power level "Raise" button (#8) to obtain reading of 2.2 Amperes on power level meter (#9).

10. Flip "MODE" toggle switch (#7) to "AUTOMATIC" position.

TO STOP:

1. When trailing end of last case reaches center of cavity, push "Microwave Power Off" button (#6).

2. Flip "High Voltage" toggle switch (#5) to OFF position.

3. When last case exits tunnel, push "CONVEYOR STOP" button (#3).

4. After 5 minutes, flip "Control" (#2) and "Standby" (#1) toggle switches to "OFF" position.

5. Close cooling water valves ("A" and "B").

SMALL LOT OPERATING PROCEDURE
(Less than 4 cases)

TO START:

1. thru 8. - same as above. NOTE: Belt speed to be 1/2 calculated RPM.

9. Jog power level "RAISE" button (#8) to obtain reading of 1.1 Amperes on power level meter (#9).

10. Same as above.

TO STOP:

Same as above.

Safety

Public Law 90-62, Radiation Control for Health and Safety Act of 1968, Code of Federal Regulations, Title 21, Chapter 1, J Part 1030 sets standards with which microwave ovens manufactured after October 1971 must comply. These standards specify acceptable levels of leakage as well as techniques to be used to demonstrate satisfactory performance.

It is important to emphasize that compliance with these standards does not eliminate potential hazards and a program of routine monitoring is important to insure safety in the regular use of these ovens.

This law does not specify the frequency with which routine surveys should be performed; however, Army Regulation 40-44 recommends that visual inspections should be performed as often as possible, at least weekly by operating personnel. A visual inspection should check for the following:

1. Loose or bent door hinges (screws missing).
2. Sprung, warped, or misaligned doors.
3. Faulty interlocks (e.g. oven operates with door slightly ajar).
4. Worn, missing or damaged seals around door or viewing area.
5. Pitting or burnt spots around door closure area.

A comprehensive survey should be performed at least every six months once a radiation protection program is established and is functioning.

A short training program on the proper survey techniques and hazard evaluation is offered as on-the-job training by the USA Environmental Hygiene Agency.

Leakage must not exceed 5 milliwatts/square centimeter at any point 5 cm or more from any external surface of the machine. This measurement must be made using an instrument which reaches 90% of its steady state reading within three seconds and has a detector with an effective aperture of 25 cm^2 or less. The instrument must have an accuracy of plus or minus 1 db.

Cleaning

The primary objective of cleaning is to prevent any buildup or dried blood or other material inside the cavity or on the conveyor belt. An accumulation of dried blood is a potential source of fire when exposed to microwave heating for a period of time. Sanitation is also to be considered, but this is of secondary importance since the material being tempered, is never in contact with any part of the machine as long as the tempering is done with the product in packing cases.

Cleaning and sanitizing can be scheduled on an as-needed basis and accomplished by hosing the interior of the machine through the cavity door with 180°F water. Most of this wash-water will be contained on the inside and can be directed to a sewer through a hose attached to the cavity drain.

Cleaning of the belt can be handled in a similar manner, except that the hosing can best be done outside the cavity. In cases where the splashing of a hose cannot be tolerated it is recommended that both sides of the belt be manually sponged with a hot detergent-sanitizing solution (FSN 930/249/8036, or 6840/810/6396) followed by a water rinse.

The belt must not be loosened nor the microwave transmitter operated during cleaning operations.